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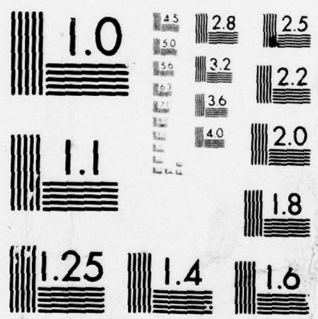

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report No. 267
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) THE AMSAA WAR GAME (AMSWAG) COMPUTER MODEL
5. TYPE OF REPORT & PERIOD COVERED: (9) Technical rept.,
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Robert D./Orlov
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, MD 21005
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: RDT&E Project No. (16) 1T765706M541
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Materiel Development & Readiness Command, 500 Eisenhower Avenue, Alexandria, VA 22333
12. REPORT DATE: (11) August 1979
13. NUMBER OF PAGES: ~~32~~ (12) 27
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC RECEIVED OCT 12 1979 A

18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AMSWAG
IUA
Bonder/IUA
Combat Simulation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

AMSWAG is a high resolution battalion level combat simulation of ground combat developed by AMSAA as a major evolution of the Bonder/IUA model. This document contains a general description of the capabilities and limitations of AMSWAG.

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CONTENTS

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ACKNOWLEDGMENT

The author wishes to acknowledge the essential efforts of Mr. Joe H. Hawkins, who developed much of the AMSWAG methodology, programs, and documentation. Appreciation is also gratefully extended to Mrs. Robin DeFranks who provided excellent and timely word processing support.

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THE AMSAA WAR GAME (AMSWAG) COMPUTER MODEL

1. INTRODUCTION

1.1 Purpose.

The purpose of this report is to provide a general description of the AMSAA War Game (AMSWAG) computer model in its current form. It is intended that this document be updated periodically with supplements to reflect changes in the model or be replaced by a new report when major modifications are implemented.

1.2 Background.

The history of the AMSAA War Game computer model began in 1968 with the Individual Unit Action (IUA) computer model. The IUA, a time-sequenced, Monte-Carlo battalion level force-on-force simulation was developed by the Lockheed Missile and Space Company in support of the Tank Antitank Assault Weapon System (TATAWS III) study. The second step occurred in 1970 with the development by Seth Bonder of a deterministic model, called the Bonder IUA, which was able to replicate the results from the earlier IUA. In 1970, AMSAA acquired two versions of this latter model and, by June 1972, both were operational on the Ballistics Research Laboratory computer (BRLESC). After extensive changes during the next two years, the model was appropriately renamed AMSWAG. The last significant milestone, in 1978, was the conversion of the model from the BRLESC computer to a Control Data Corporation (CDC) CYBER 70 computer.

The chronology of the AMSWAG model, together with major modifications and improvements, is presented in Figure 1.

1.3 Usage.

The first major usage of AMSWAG was for the BUSHMASTER Cost Effectiveness Analysis (COEA) in 1974. In all, AMSWAG has been used in approximately twenty studies to address such diverse questions as the evaluation of individual weapon systems or subsystems, determination of optimum weapon mixes, and the identification and role of critical battlefield parameters such as camouflage, smoke, and limited visibility.

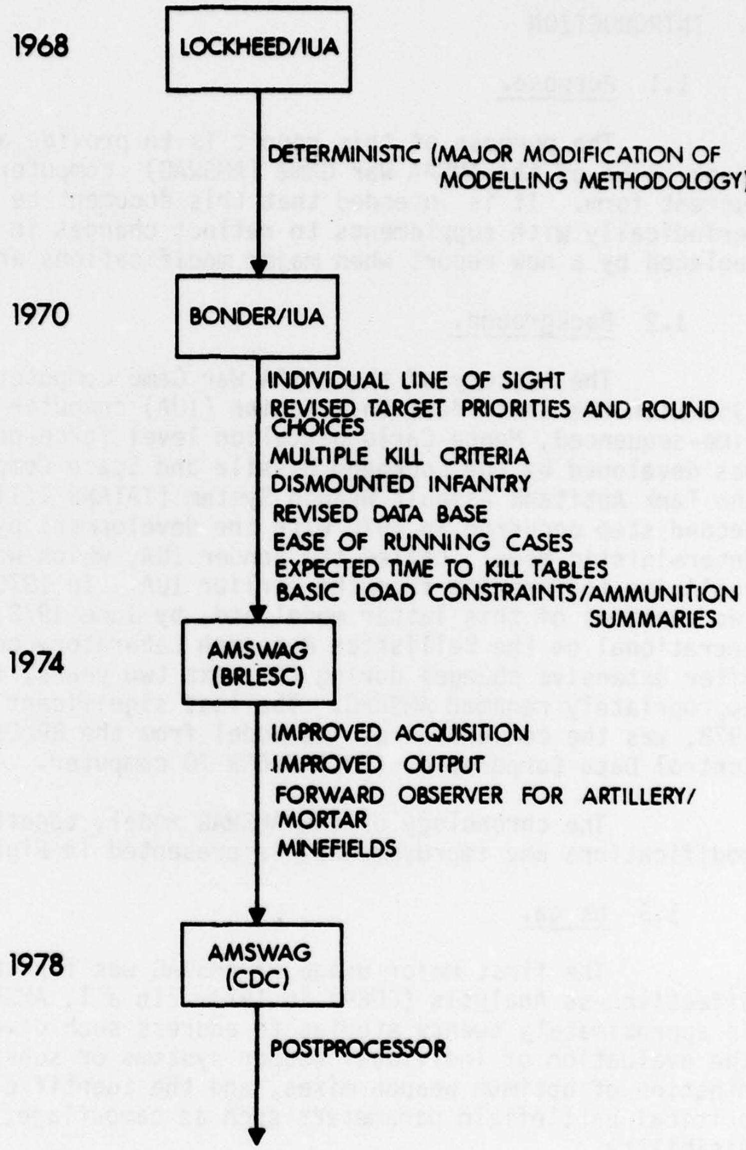

Figure 1. Historical Background of AMSWAG.

2. THE AMSWAG MODEL

2.1 General Description of the Model.

The AMSWAG model is a computer war game of a typical battalion level attack/defense. At the mathematical level, the model is deterministic, time-sequenced, and second-order Lanchester.

AMSWAG is supported by a set of preprocessor and postprocessor programs. A general flow diagram of the essential blocks in the overall AMSWAG process is presented in Figure 2, and a detailed flow diagram of the individual programs in Figure 3.

The preprocessor programs provide mobility and intervisibility data estimates, vulnerability data estimates, and weapon and round data estimates to AMSWAG. The postprocessor program conveniently summarizes important statistics of a game.

The defender force, normally a reinforced company, is deployed in fixed positions (maximum of sixty). The attacker force, normally a battalion, moves along predetermined paths of advance (maximum of twenty-four). Additionally, the attacker force is allowed overwatch positions (maximum of fifty) which can fire but cannot move. Each defender and attacker unit consists of a homogeneous group of weapons such as M60A3 tanks. An example of a map region, together with overlaid defender positions and attacker paths of advance, is presented in Figure 4.

AMSWAG conducts the battle in uniform time steps of ten seconds each. The primary processes considered during each interval are target acquisition, target prioritization, target allocation, firer suppression, attacker dismount, and target attrition. Attrition is basically comprised of three types: direct fire, indirect fire (artillery and mortar), and minefield. At the end of each interval, the number of survivors in each unit is reduced by the attrition to the unit and the ammunition levels are updated as well. Also, AMSWAG prints rather detailed output, including total vehicle and personnel losses on each side, vehicle exchange and force ratios, status of surviving units, and victim-killer scoreboards (number of kills as a function of weapon type versus weapon type). The normal termination point of a battle is a specified level of losses to either side.

AMSWAG, a high resolution model, often plays individual weapons. Moreover, in its treatment of these weapons, it considers weapon system characteristics such as spatial dimensions, armor protection, and acquisition capabilities. It also allows for the inclusion of environmental features, such as natural and man-made obstacles, towns, and forests, which add realism to a battle situation.

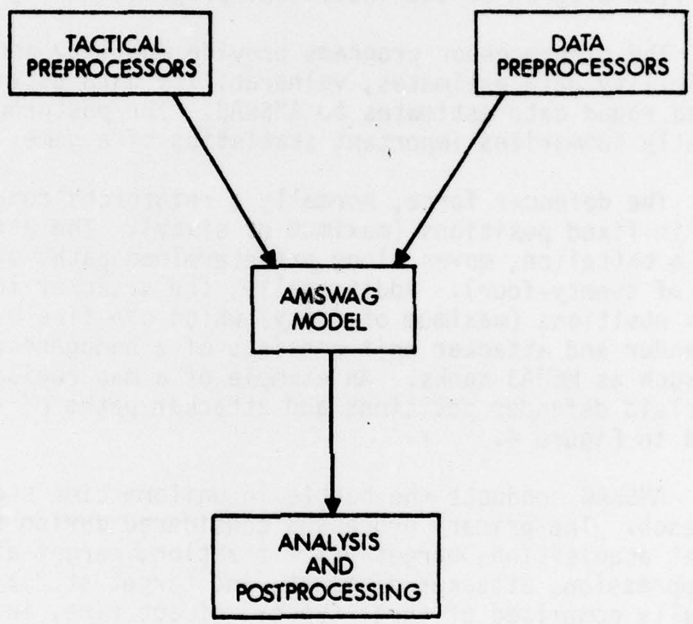

Figure 2. The AMSWAG Process (General)

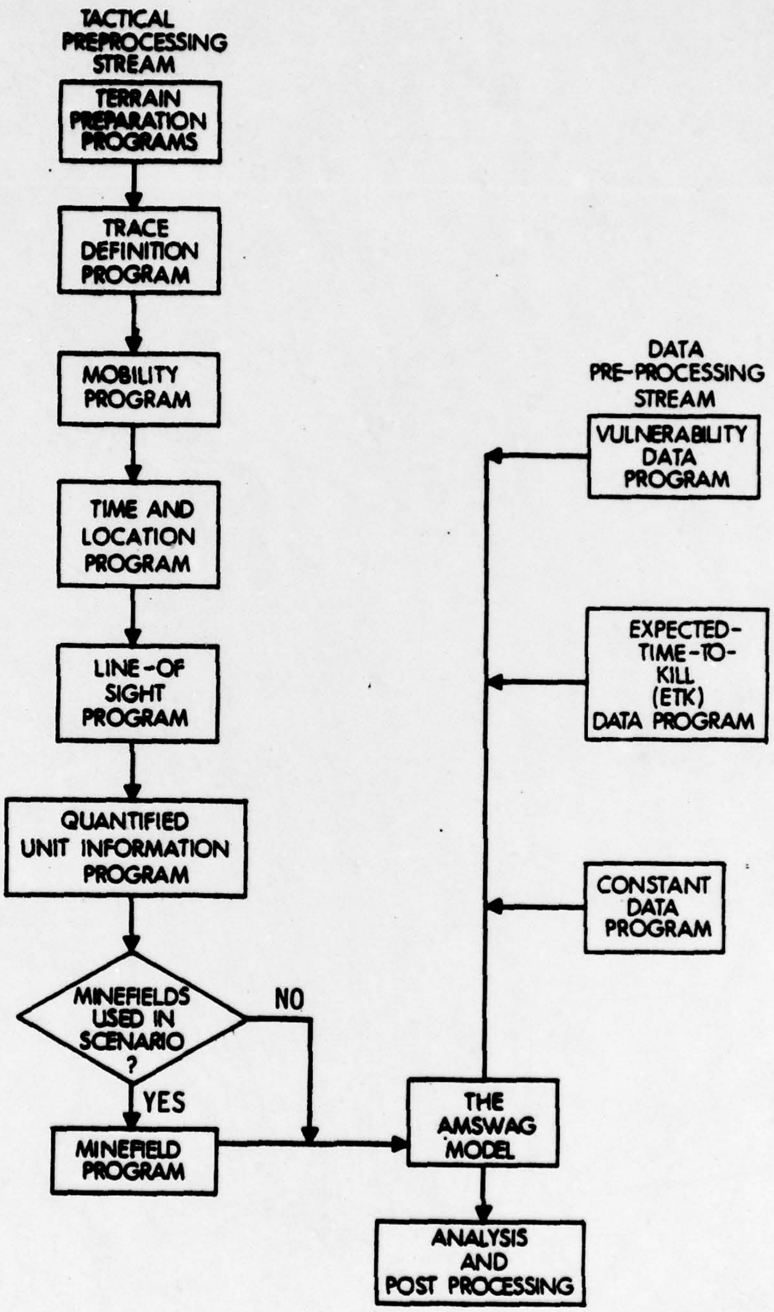

Figure 3. The AMSWAG Process (Detailed).

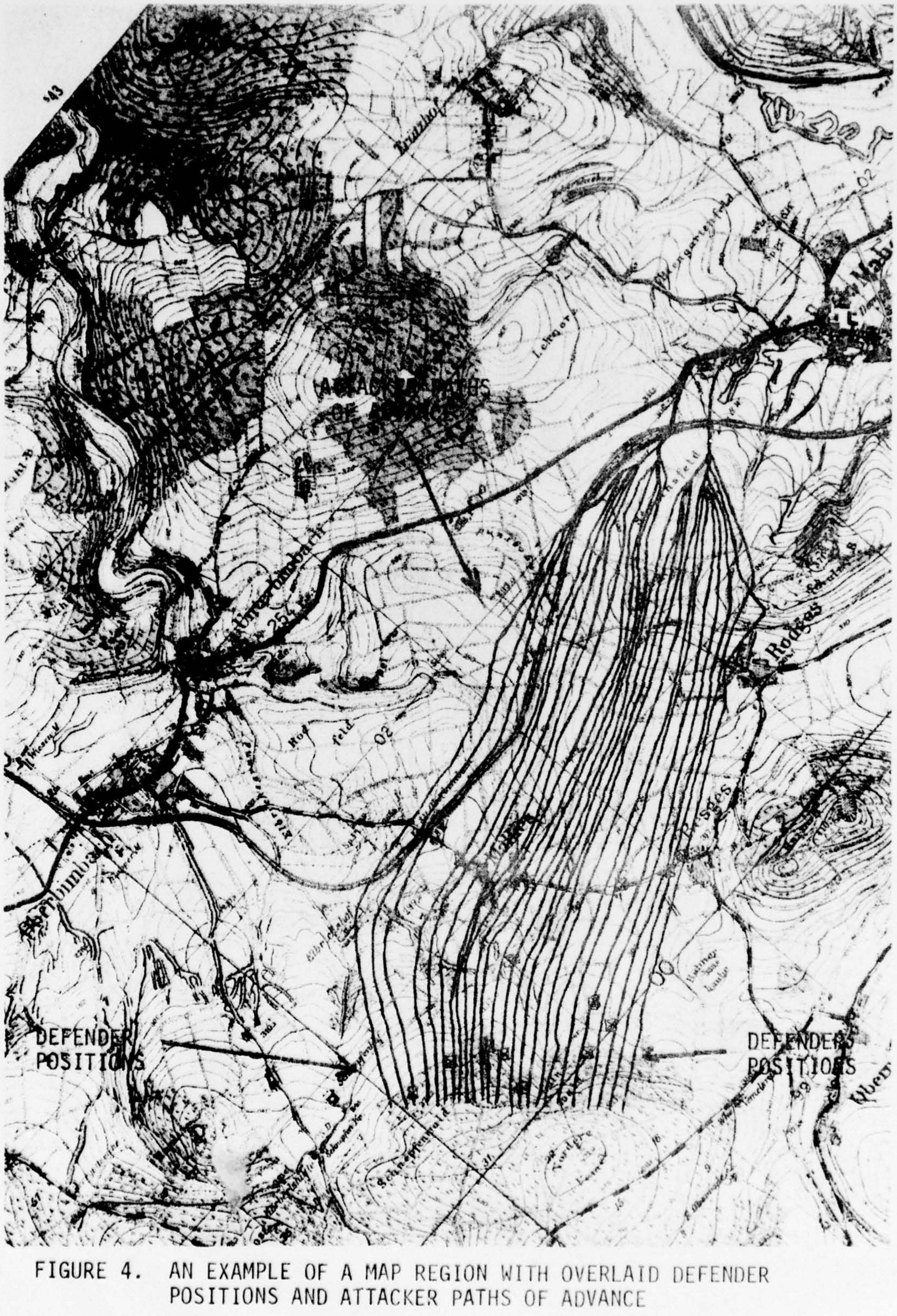

FIGURE 4. AN EXAMPLE OF A MAP REGION WITH OVERLAID DEFENDER POSITIONS AND ATTACKER PATHS OF ADVANCE

2.2 Limitations.

AMSWAG is limited in its capacity to simulate all of the aspects of battle usually considered important in a battalion level interaction. Some of the known aspects not played or accounted for are:

1. Defender movement
2. Helicopter/close air support
3. Command, control, and communications (C^3)
4. Weapon systems dependent upon C^3
5. Interactive decision points
6. False targets
7. Logistics
8. Readiness and morale

It only plays minimally:

1. Tactics (since the tactics are virtually all preprocessed)
2. Smoke and dust
3. Interaction of terrain, target exposure, and firing engagement process

2.3 Preprocessed Data Estimates.

The majority of the input data estimates for the model is preprocessed and stored on mass storage because of the large amount of inputs required by the model (approximately 250,000 numbers per case) and because of the similarity of many cases. The data estimates are stored in a packed form which reduces computer memory significantly.

2.3.1 Terrain and Mobility Data Estimates.

Terrain and mobility data estimates and movement rules are required for the proper movement of attacker units along their designated paths. The necessary terrain data are the gradient, soil type, and terrain roughness. The necessary mobility data consist of the maximum performance or tactical velocity for each type of attacker maneuvering vehicle. Lastly, any necessary movement rules such as bounding, follow-on, stops, and phasing of the attack are also considered.

2.3.2 Location and Velocity Data Estimates.

The terrain and mobility data estimates and movement rules generate location and velocity data for each unit for each ten second period of the game. During an actual game, some limited modification of the preprocessed location and velocity data is permitted by the use of special input cards.

2.3.3 Intervisibility Data Estimates. Intervisibility or line-of-sight (LOS) data estimates are preprocessed for each opposing pair of units for each ten second period of the game. For each pair, three intervisibility possibilities exist:

a. Line-of-sight does not exist .

b. Line-of-sight exists and attacker is fully exposed and defender is hull defilade.

c. Line-of-sight exists and both the attacker and defender are hull defilade.

Note that, if line-of-sight exists, then the defender is automatically hull defilade.

2.3.4 Minefield Data Estimates. If minefields are being played, then, for each attacker maneuver unit and for each ten second period of the unit's path, two data estimates are required. The estimates are the type of mine and the expected number of mines encountered.

2.3.5 Vulnerability Data Estimates. Two basic types of vulnerability data estimates are used by the model.

Probability of Kill Given a Hit Estimates[1]

Target vulnerability estimates for single shot armor piercing (AP) and high explosive antitank (HEAT) rounds consist of sets of probabilities of kill given a hit, P(K/H), estimates. These estimates are a function of:

a. Round Fired
b. Target
c. Range
d. Dispersion (circular, in 1 foot intervals measured from nominal aimpoint on target)
e. Kill criteria (mobility (M), firepower (F), mobility or firepower (M or F), and expected casualties or squads (EC))

---

[1]The use of the term "kill" here and in the rest of the text is possibly misleading. Although the term is relatively standard in the literature of wargaming, the term actually denotes a state of sufficient incapacitation or damage to a vehicle or personnel such that either is ineffective at least for the remainder of the battle.

f. Target exposure (hull defilade or fully exposed)

g. Angle of presentation of the target (in 30 degree increments from 0 degrees to 180 degrees (cardioid average currently used)).

Expected Time to Kill Estimates

The lethality estimates for rapid fire weapon systems and for single shot high explosive rounds consist of sets of expected time to kill (ETK) estimates. These estimates are a function of:

a. Round fired
b. Target
c. Range (interval varies)
d. Kill criteria (M, F, M or F, and EC)
e. Target exposure (hull defilade or fully exposed)
f. Target motion
g. Firer motion

For each set of expected time to kill estimates, there are one or more corresponding sets of estimates. If the target is a vehicle, the additional set consists of expected numbers of rounds to kill the target. If the target is personnel, the additional sets consist of rates of fire and attrition coefficients (see Direct Fire Attrition - Personnel Targets).

2.3.6 Weapon and Round Data Estimates. Weapon systems and their rounds are represented in the model as sets of data estimates which contain all the characteristics of the weapons and rounds that are needed by the model. These characteristics include:

a. Time of flight (function of range)
b. Maximum effective range
c. Biases and dispersions used to compute hit probabilities (function of range, firer motion, and target motion)
d. Response times (function of range for first and subsequent rounds)
e. Vehicle dimensions (hull and turret)

2.4 Sequence of Events in Each Time Interval.

AMSWAG repeats the same sequence of events during each ten second interval of a game. For the most part, the model does not maintain knowledge of what has happened during the preceding intervals. Most of the decisions about what to do during an interval are based on the conditions that exist during the interval and not on what happened during the preceding intervals. The basic program sequence of events for each interval is described in the following paragraphs.

2.4.1 Target Acquisition.

Target acquisition between a particular firer and target in this model occurs by two methods, namely, launch signature acquisition (firing) and random search (nonfiring).

Launch signature acquisition is essentially entered as the probability of determining an accurate location of the target when it has fired a round. The current data base for this method of acquisition is based primarily on several field tests.

Random search acquisition for a particular firer-target combination is treated as an exponential distribution of the time to accurately acquire the target. The primary data estimate inputs to this distribution, generated by a program developed by the US Army Night Vision Laboratory (see Reference 10), are the probability of ultimate acquisition and the mean time to acquire (given acquisition occurs). Another input is the length of time for which continuous line-of-sight has existed between the firer and target. As this length of time increases, the probability of random search acquisition accumulates.

In general terms, the probability of acquisition between a firer and a target is:

$$1 - \left[\text{(probability of no firing acquisition)} \times \text{(probability of no nonfiring acquisition)} \right]^{NT}$$

where NT is the number of elements in the target unit.

At an interruption in line-of-sight, the probability of acquisition is set to zero. With a resumption in line-of-sight, target acquisition begins again.

Acquisition is the first event to occur during a time interval. Nevertheless, any additional acquisition that occurs during the interval is not used until the next interval, since the additional acquisition represents new knowledge gained during the interval.

2.4.2 Assessment. The results of all attrition during an interval are recorded and the number of survivors in each unit is reduced by the amount of attrition suffered by that unit. A unit may suffer a mobility (M) kill, a firepower (F) kill, or some combination of these kills. Expected casualties (EC) to squads mounted within armored personnel carriers are also assessed. The ammunition status (amount expended, destroyed, and remaining) of each unit, the suppression to each unit, and the game clock are updated.

2.4.3 Suppression. The basic assumption in the suppression methodology is that the amount an individual target unit (such as one tank) is suppressed is a function of the attrition that the unit has recently suffered. The probability of being suppressed at time $(t + \Delta t)$ is given by:

$$P_S(t + \Delta t) = \bar{S} + (1-\bar{S}) \cdot P_S(t) \cdot e^{-\Delta t/\mu_S}$$

where

$$\bar{S} = \frac{e^{\beta}}{e^{\beta}+1}$$

$$\beta = 10 \cdot e^{-\left[(.04/\rho) \cdot (1-\bar{f})^2/\bar{f}\right]} - 5$$

$\bar{S}$ = Probability of being suppressed in the interval $(t, t + \Delta t)$

$P_S(t)$ = Probability that a surviving unit is suppressed at time t

μ_S = Mean duration time of suppression

ρ = Human factors coefficent

The coefficient has been judgementally determined.
- $\rho = 1$ represents a unit which is suppressed with normal ease.
- $\rho > 1$ represents a unit which is suppressed with more than normal ease.
- $\rho < 1$ represents a unit which is suppressed with less than normal ease.

$\bar{f}$ = Fraction of unit killed in interval $(t, t + \Delta t)$

Additional information on the methodology and the above parameters can be found in Reference 7. Figure 5 shows $\bar{S}$'s for various ρ's and $\bar{T}$'s.

The fraction of a unit which is suppressed retains its current target acquisition information, continues to acquire and be acquired at the same rate, and continues its normal movement. The major difference between a suppressed and an unsuppressed portion of a unit is that a suppressed portion of a unit, although it fires along with the rest of the unit, inflicts no attrition. This results in a lower probability of kill per shot for each weapon system that becomes suppressed.

The current suppression methodology in AMSWAG is only one of several alternative methodologies in existence. It may be replaced by another methodology when sufficient evidence is provided. If desired, suppressive effects may be zeroed out of AMSWAG.

2.4.4 Dismount. At this time in the event cycle, dismount criteria are checked to determine if the attacker personnel carriers are ready to dismount. The criteria are a specified range interval between the attacker and defender and a specified fractional loss of attacker mobility. Typically the range interval is 300 meters to 1500 meters and the fractional mobility loss is 30 percent or more. If a dismount on one axis occurs, all the vehicles on that axis halt, and the squads follow the preplanned routes at a much reduced rate of speed. An input option allows the vehicles which have not suffered a mobility loss to follow at some specified distance if desired.

At present, the dismount capability has not been tested or exercised within the last few years.

2.4.5 Movement. After the acquisition and assessments have been completed for an interval, the location, velocity, and line-of-sight data estimates required for the next interval are read from mass storage. These estimates are used in determining the attrition rates for the new interval.

2.4.6 Output. At the end of each ten second interval, the model prints the following outputs:

a. Total vehicle and personnel losses for each side.
b. Ranges between forces.
c. Current vehicle exchange ratio (total Red vehicle losses/ total Blue vehicle losses)
d. Current vehicle force ratio (total surviving attacker vehicles/ total surviving defender vehicles)
e. Game time

At the end of each sixty seconds of game time, and at the end of the game, a more complete output summary occurs. This summary

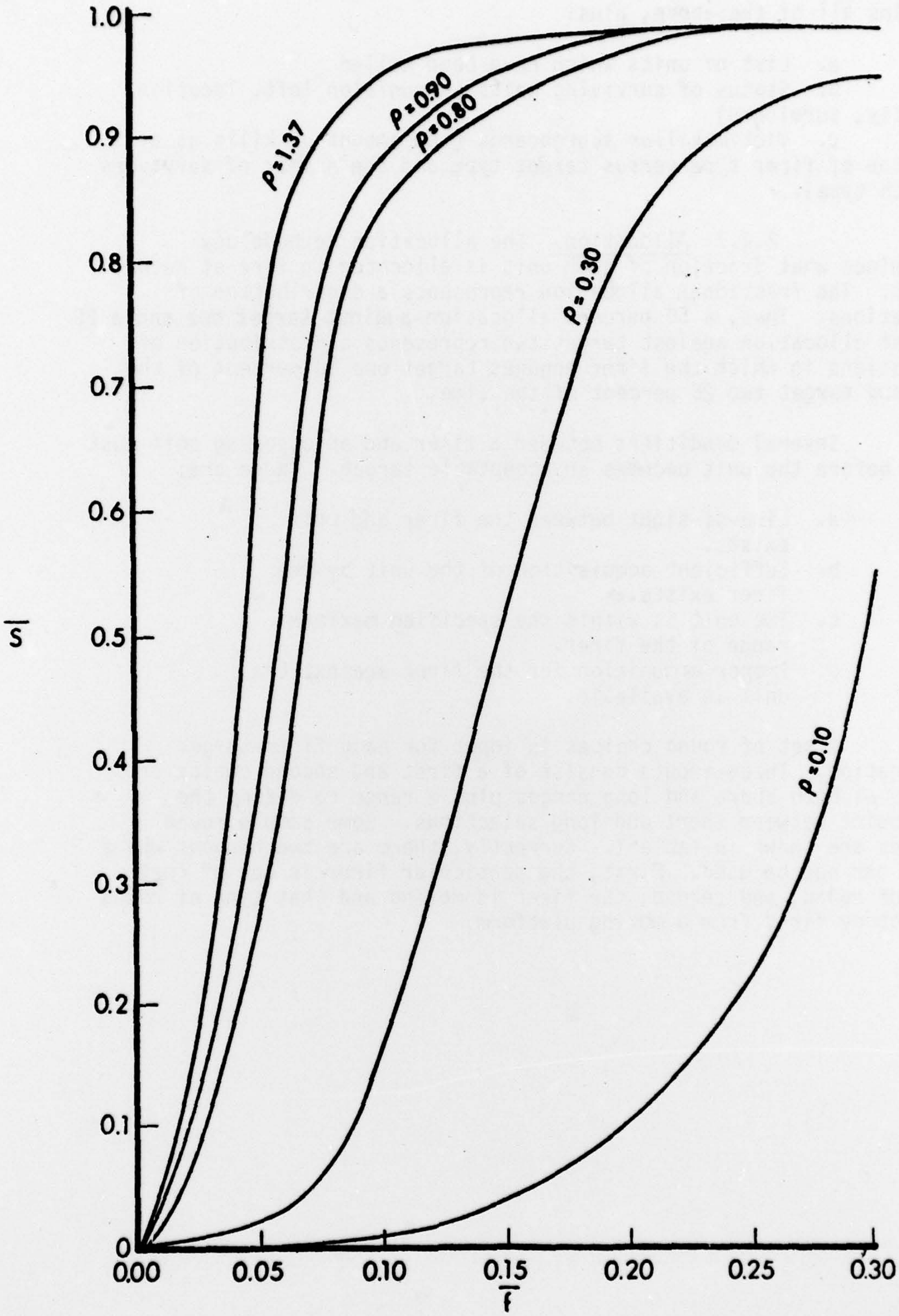

Figure 5 (U) Probability of Being Suppressed ($\overline{S}$)

contains all of the above, plus:

a. List of units which have been killed

b. Status of surviving units (ammunition left, location, velocity, survivors)

c. Victim-killer scoreboards (the amount of kills as a function of firer type versus target type and the number of survivors of each type).

2.4.7 Allocation. The allocation methodology determines what fraction of each unit is allocated to fire at each target. The fractional allocation represents a distribution of allocations. Thus, a 50 percent allocation against target one and a 25 percent allocation against target two represents a distribution of allocations in which the firer engages target one 50 percent of the time and target two 25 percent of the time.

Several conditions between a firer and an opposing unit must exist before the unit becomes an acceptable target. These are:

a. Line-of-sight between the firer and unit exists.
b. Sufficient acquisition of the unit by the firer exists.
c. The unit is within the specified maximum range of the firer.
d. Proper ammunition for the firer against the unit is available.

A set of round choices is input for each firer-target combination. These inputs consist of a first and second choice of rounds at both short and long ranges plus a range to define the breakpoint between short and long selections. Some sample round choices are shown in Table 1. Currently, there are two reasons why a round can not be used. First, the particular firer is out of that type of round, and second, the firer is moving and that type of round can not be fired from a moving platform.

TABLE 1 SAMPLE ROUND CHOICES

FIRER	TARGET	1ST CHOICE SHORT RANGE	1ST CHOICE LONG RANGE	2ND CHOICE SHORT RANGE	2ND CHOICE LONG RANGE	RANGE
M60A3	BMP	HEAT	APDS	APDS	HEAT	1500
M60A3	SQUAD	COAX	HEP	HEP	HEAT	1000
MICV	ATGM	COAX	HE	HE	COAX	1000
BMP	MICV	73MM HEAT	SAGGER	73MM HEAT	SAGGER	800
M113/ TOW	T62	TOW	TOW	TOW	TOW	1250

An input linear target priority scheme, based upon target type and range, next ranks all of the units which satisfy the above conditions. A representative scheme for a BMP firer type is presented in Figure 6. As an aid in understanding the scheme, a target T_1 at range r_1 is of higher priority than a target T_2 at range r_2 if the plot of T_1 at the value r_1 is higher than the plot of T_2 at the value r_2. Thus, as can be seen from the sample scheme, a TOW target at 2000 meters is of higher priority than a DRAGON target at 1800 meters.

If a more curvilinear target priority scheme is needed, then the AMSWAG program can be appropriately modified. As an example of the need, an infantry weapon may be completely ineffective at middle to long range targets but very effective at short range targets.

Finally, a firer allocates against his highest priority target a portion of himself equal to his acquisition of the target, against his next-to-the-highest-priority target a portion of himself equal to his acquisition of the target multiplied by his unallocated portion, and so on. A firer continues allocating himself until he either runs out of targets or he has allocated more than 98 percent of himself.

As an example of the methodology, suppose a firer has acquired three targets, T_1, T_2, and T_3 with probabilities of acquisition of 50, 50, and 20 percent respectively. Moreover, suppose that T_1 is the highest priority target, T_2 is the next priority target, and T_3 is the last priority target. Then the firer allocates 50 percent of himself against T_1, 25 percent of himself against T_2 (50 percent acquisition multiplied by his unallocated portion of 50 percent), and 5 percent of himself against T_3 (20 percent acquisition multiplied by his unallocated portion of 25 percent).

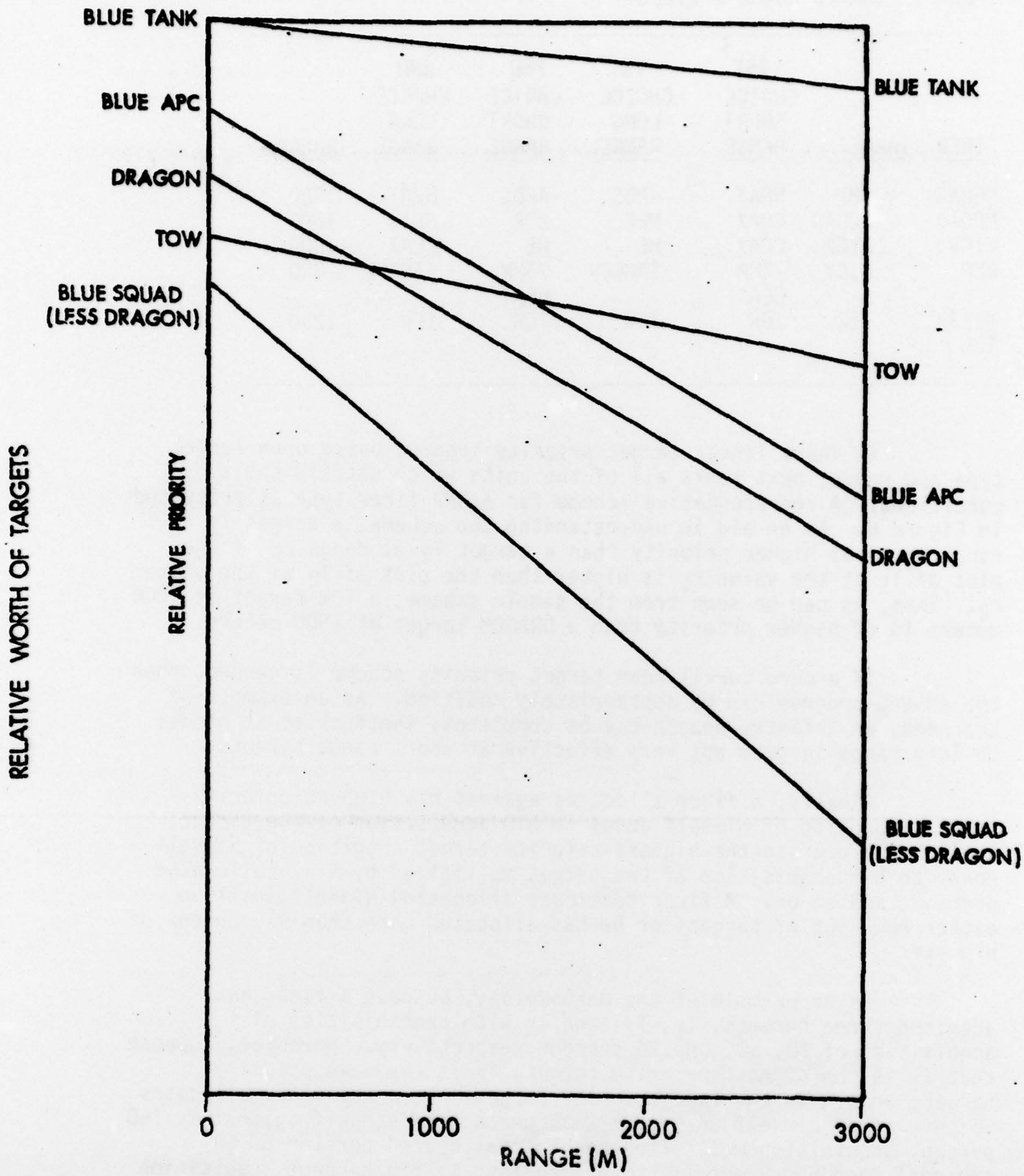

Figure 6. Typical Target Priorities for a BMP Firer, Europe & Blue Attack.

2.4.8 Attrition.

Direct Fire Attrition - Vehicle Targets. Two major factors drive the results of direct fire attrition in the AMSWAG model. These are the amount of fire allocated and the expected time to kill (ETK) the target. For rapid fire weapon systems, such as machineguns, the ETK is a tabulated value (see paragraph, Expected Time to Kill Estimates). However, for other rounds, the model computes the expected time to kill. A detailed description of the mathematical derivation of the ETK formula, based upon a semi-Markov model, is contained in Reference 2. In the (AMSWAG) development of ETK, an expected number of rounds to achieve a kill is first obtained. The formula for ETK is:

$$ETK = t_1 - t_s + \left\{\frac{t_s + t_f}{P(K/h)}\right\} + \left\{\frac{t_s + t_f}{P(h/m)}\right\} \cdot \left\{\frac{1-P(h/h)}{P(K/h)} + P(h/h) - P(h_1)\right\}$$

where

t_1 = Time to fire first round

t_s = Time to fire subsequent round

t_f = Time of flight

$P(K/h)$ = Probability of kill given a hit

$P(h/m)$ = Probability of hit given a miss

$P(h/h)$ = Probability of hit given a hit

$P(h_1)$ = Probability of hit on first round

Most of the parameters in the ETK formula vary as a function of range, target motion, firer motion, and target exposure. The probability of hit values used are those for a cardioid average of the angle of presentation of the target.

Once the ETK has been determined, the attrition A_{ij} by firer i against target j in this interval is given by:

$$A_{ij} = f_{ij} \cdot S_i \cdot U_i \frac{\Delta t}{ETK_{ij}}$$

where

f_{ij} = the fraction of firer unit i allocated to target j

S_i = the number of survivors in firer unit i

U_i = the fraction of unsuppressed firers in unit i

Δt = the game time interval (10 seconds)

ETK_{ij} = the expected time for one firer of unit i to kill one target of unit j under the conditions existing in this interval

Note that $\frac{1}{ETK_{ij}}$ is the attrition rate in kills per second for one firer i versus one target j.

Direct Fire Attrition - Personnel Targets

For personnel targets such as squads, an exponential function is used to determine attrition. The fraction of casualties sustained in an interval, B_{ij}, is given by

$$B_{ij} = (1 - e^{-\delta_{ij} \Delta t}) \cdot \left\{ \frac{t_{.70} - t_o}{t_{.70}} \right\}$$

where

B_{ij} = the fraction of casualties inflicted by firer i against target j

δ_{ij} is determined outside the AMSWAG model and is a table value read into the model as a part of ETK data (see paragraph Expected Time to Kill Estimates)

$t_{.70}$ = the expected time to kill 70 percent of the target

t_o = the time required for the initial lay on the target

A personnel target is considered ineffective and is removed from the game when it has suffered 70 percent losses.

Indirect Fire Attrition

During the preparatory fires phase, indirect fire attrition is only computed against targets located in preplanned artillery concentrations. Any target already located in a concentration region or one that moves into a preplanned location receives some fractional amount of artillery or mortar fire. After the preparatory fires phase, attrition is only computed against targets acquired by units designated as forward observers. An algorithm has been derived to compute the indirect fire attrition in the AMSWAG model. The algorithm is:

$$\bar{f} = 1 - \frac{a + i\Delta t}{a + (i+1)\Delta t}$$

where

$\bar{f}$ = the fraction of a target attrited during this interval.

i = the number of previous intervals this target has received indirect fire.

a = an estimate of the amount of time required for one indirect fire unit (battery of artillery/company of mortar) to attrit half of a particular target. The estimate is averaged over the mix of different tubes and munitions available and types of terrain (woods versus open fields). An estimate is needed for each particular target. Additional information about this estimate is contained in Reference 9.

During the preparatory fires phase, the estimate a is adjusted for the actual number of indirect fire units allocated against the target. After the preparatory fires phase, the estimate a is adjusted according to an allocation priority scheme similar to the scheme for direct fire weapons. Briefly, the allocation is recursively defined in terms of target priority and the amount of forward observer acquisition.

Minefield Attrition.

Minefield attrition in AMSWAG is computed against units attempting to cross minefields. In an attrition calculation for a unit within a minefield, a minefield density computed originally from a preprocesser program, a probability of detection and activation of a mine by a unit, and a probability of a kill to a unit by a mine are considered. In somewhat more detail, the following assumptions are employed:

a. The number of mines (density in the path of a unit during a ten second period) is a Poisson random variable.

b. Mines are detected and destroyed independently of each other.

c. An undetected mine is activated independently of previous events and, if activated, is destroyed.

d. A unit activating a mine survives independently of previous events.

2.5 Ammunition Expenditures.

After each firing event for a firer-target-round triplet, round expenditures for the event are computed. Also, the expended number of rounds is cumulatively added to the total number of expended rounds and subtracted from the remaining number of unexpended rounds for the particular firer and round.

The round expenditure for each firing event is computed as follows. First, the ammunition rate (rounds per second) is determined. For non-personnel type targets, it is the ratio of the expected number of rounds required to kill the target divided by the time to kill the target; for personnel type targets, it is simply a stored data number. Next, the ammunition rate is multiplied by the timestep (10 seconds) and by the number of allocated firers in the firing unit to yield the round expenditure.

If a target suffers any attrition, then an ammunition loss directly proportional to the attrition of the target is subtracted from the ammunition available to the target.

2.6 Primary Analysis Point.

The normal method of terminating the battle is to play the game until a specified level of losses is achieved by either side. This condition, called the primary analysis point, varies from study to study but is typically assumed to be 60 percent vehicle losses for either side.

2.7 Areas for Future Enhancement.

The AMSWAG model remains in a continual state of development. Improvements in the following methodologies are planned:

a. suppression
b. acquisition

Also, addition of each of the following to the model is planned:

a. defender movement methodology
b. smoke and dust methodology
c. post-processing to include graphic display
d. other end of game criteria.

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